

BELLCOMM, INC.

955 L'ENFANT PLAZA NORTH, S.W.

WASHINGTON, D. C. 20024

SUBJECT: Apollo Consumables Report -
LM Quick Look Capability -
Case 320

DATE: December 30, 1968

FROM: R. D. Raymond

ABSTRACT

Many consumables analysis techniques have been developed by NASA and Apollo contractors and several of these methods are evolving with the Apollo program to improve their usefulness. One method obtained from MSC, Mission Planning and Analysis Division, is a simplified LM electrical power subsystem program that provides a quick look capability for electrical energy, water, and oxygen expenditure predictions. This method is described and an example based on the first lunar landing (mission G-1) is discussed.

The LM quick look program is based on a mission modular data book approach. Inputs to the computer program are mission block times and consumable usage rates. The outputs provided include consumables remaining after each mission phase. This method is convenient to use for preliminary mission planning and can give sufficient accuracy for this purpose if the inputs are valid.

The mission G-1 analysis demonstrates an application of the subject method and emphasizes the need to accurately define input data. Based on the results of the analysis some consumables are marginal. The low margins indicate a need to perform additional consumables analyses. Also, more careful evaluation of inputs is needed to assure that the results are valid before relying on them.

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- LM QUICK LOOK CAPABILITY (Bellcomm, Inc.)
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MEMORANDUM FOR FILEINTRODUCTION

In the course of planning Apollo missions, and in subsequent evaluations of flight data, it is necessary to have valid analytical methods for predicting and comparing spacecraft consumables usage. Consumables analysis methods have been developed by NASA and Apollo contractors to support mission plans and evaluations. Several of these methods are evolving with the Apollo program to improve their usefulness through increased accuracy or flexibility. The resulting changes emphasize the need to understand the methods in order to validly use the consumables calculations.

We at Bellcomm need both to perform consumables analyses to support engineering studies and to use NASA consumables reports to support mission planning. Therefore, we have acquired several procedures used for consumables analyses at MSC. One of these methods provides a quick look analysis of LM consumables, as described in this report.

The LM quick look consumables analysis method is based on a simplified LM electrical power subsystem program devised by the Consumables Analysis Section, Guidance and Performance Branch, MSC⁽¹⁾. The program computes LM electrical energy, oxygen and water requirements, based on mission block usage rates.

The analysis method is described in the following section. Then an example of applying this analysis method to the first lunar landing mission is discussed, followed by current conclusions on the application of the method and resulting data.

ANALYSIS METHOD

The LM quick look consumables analysis method uses a simple digital computer program to calculate expended commodities versus mission time for specified expenditure rates. The consumables computed are electrical energy, water and oxygen. The program is written in Fortran for use on a Univac 1108 digital computer.

The computer program accepts input data as provided by the Universal Mission Modular Data Book and modifications as specified for a particular mission requirement.⁽²⁾ The required input data are initial total consumable quantities, mission phase (block) time (start and end), block power, changes in block power, metabolic rate, oxygen leakage rate, water for PLSS refill, and oxygen for cabin repressurization and PLSS refill. The consumables usages are computed for each phase from the phase time and usage rate. If the total usage rate for one commodity is dependent on another commodity usage rate, the program computes both the dependent rate and the quantity used.

Electrical energy is calculated by multiplying the block rate (watts) by the phase time. The energy used in each sequential phase of a mission is subtracted from the specified batteries (ascent or descent). The resulting outputs are ascent and descent energy used and remaining for each phase. The input data can be adjusted to represent specific mission requirements by specifying a delta power and the planned phase start and end times.

Water requirements are calculated using a constant rate for structural heat control (1 lb/hr.) and urine loss (0.11 lb/hr/man) plus variable losses proportional to electrical heat and metabolic rates. The electrical control water requirement in lbs/hr. is $0.0027 \times \text{power in watts} - 0.0650$. The water requirement (in lbs/hr.) that is proportional to metabolic rate is estimated as $112.43 \times 10^{-5} \times \text{metabolic rate in BTU/hr.}$ Water used for PLSS refill is added from input data in the phase required. Outputs are the ascent water and descent water remaining after each sequential mission phase.

Oxygen requirements are calculated from the cabin leakage rate (0.2 lbs/hr.), metabolic rates, cabin repressurization quantities and PLSS refill quantities. The oxygen usage rate in lb/hr proportional to metabolic rate is estimated as $1.643 \times 10^{-4} \times \text{metabolic rate in BTU/hr.}$ Oxygen used for cabin repressurization and PLSS refill is added from input data in the phase required. Outputs are the ascent oxygen and descent oxygen remaining after each sequential mission phase.

The LM consumables method described provides a rapid and relatively flexible means of computing LM consumables requirements with one computer run for each mission description. The prime assets of this method are simplicity and convenience. The accuracy provided is limited by the accuracy of the input data. For example, the general estimate of accuracy for consumables computations based on the Mission Modular Data Book parameters is $\pm 10\%$. However, the accuracy can be improved by modifying the data book parameters to more precisely match specific

mission parameters as they are determined. If sufficient care is taken in determining the input parameters, this method will give results compatible with the needs of preliminary mission planning. A more accurate method, e.g., a more precise mission simulation program, should be used for the final analysis of a mission.

MISSION G-1 PRELIMINARY ANALYSIS

An analysis of the first lunar landing mission LM consumables was performed as an example of the application of the subject method. This analysis does not presume that the outputs presented herein accurately predict the mission G-1 consumables usage. However, this analysis can serve as a baseline for further input data validation and mission planning. The method of establishing the input timeline and consumables rates data used and the resulting consumables expended are described below.

A mission timeline was derived from the LM timeline presented at the mission review of the first lunar EVA.⁽³⁾ The lunar surface time was increased slightly to allow a longer rest period, resulting in a 22 hour surface stay time with one EVA period. The LM timeline was integrated into the overall mission timeline given in Mission G Spacecraft Reference Trajectory by synchronizing the lunar orbit insertion (LOI) initiation times.⁽⁴⁾ Within this time frame, individual phase activities were estimated primarily based on the Mission Modular Data Book.⁽²⁾ The timeline phases are itemized in Table I. This table lists the "Phase Name" and "Block No." selected from reference 2. The "Mission Time" is the starting time of each phase in hours, minutes and seconds measured from lift off and "Phase Time" is the phase duration in hours. The "Rate x 7.5" column in Table one lists the electrical power, including 7.5% for distribution losses, for each phase.

The consumables block usage rates were based on reference 2. However, the electrical power was modified to present specific requirements anticipated for Mission G-1. Modifications to the power requirements were made using data from an MSC lunar landing mission LM descent power budget study and two subsequent studies of the descent power budget at Bellcomm.^(5,6,7) The electrical power budget used in this analysis is plotted in Figure 1. Although it is assumed that these data are more accurate than direct application of the data book parameters, they should be updated or validated by more recent requirement predictions before this analysis output is used for any critical mission evaluations.

Outputs of electrical energy were plotted as shown in Figure 1. A liberal use of power is indicated by the power profile curve, i.e., systems were not powered down to obtain maximum available conservation of energy. This usage appeared reasonable because the lunar stay time for mission G-1 is much shorter than the nominal design reference mission. The watt-hours consumed and remaining curves indicate the consumables status throughout the mission. The descent stage four-battery capacity (46.9 KWH initially) is reduced to 33 KWH at touch-down and 1.2 KWH before lift off. The ascent stage two-battery capacity (17.8 KWH initially) is reduced to 16.2 KWH at lift off, 8 KWH after docking and 5.8 KWH after crew transfer to the CSM.

The electrical energy calculations indicate a need to conserve consumables, even though the mission has been shortened by eliminating one EVA period. The high electrical consumption is partly attributed to using larger power values than in the data book in some periods, but to a larger extent is caused by the fact that the overall LM mission timeline is essentially as long as previously planned for a two EVA mission. The lunar stay time has been decreased by over 3 hours, but the overall time from LM power on prior to descent to crew transfer after ascent is about 35 hours. This is comparable to the time used in reference 5.

The water and oxygen outputs are shown in Figure 2. The descent water remaining is 92 lbs. of approximately 314 lbs. loaded and the oxygen remaining is 20 lbs. of about 45 lbs. loaded. In the ascent stage 40 lbs. of the initial 80 lbs. of water remain and about 2 lbs. of oxygen are left of the initial 4.1 lbs. These margins may be sufficient, but they also indicate a need to conserve consumables to accommodate contingencies, e.g., loss of one ascent water or oxygen tank.

This mission G-1 analysis demonstrates the applicability of the quick look consumables analysis method. It also highlights the need to accurately identify the timeline duration and operations and the consumables block usage rates in order to obtain valid results. The accuracy of the analysis can be improved by incorporating new input data as it is acquired for either one or more blocks at a time.


CONCLUSIONS

The MSC quick look LM consumables analysis program performs well and should provide useful outputs if care is taken in specifying accurate input usage rates and phase times. The program provides a convenient tool for preliminary mission planning.

Our understanding of MSC's consumables predictions is enhanced by acquisition and study of this LM consumables program. New acquisitions of MSC analyses using this method can be helpful in understanding MSC's mission plans and in improving our ability to support engineering analysis of proposed missions and configurations.

Analysis of the G-1 mission indicates that, although the mission has been simplified, careful consideration of the conservation of consumables is still required. However, the input data used in this study must be validated or improved before relying too heavily on the results.

2033-RDR-fmw


R. D. Raymond

Attachments

References

Table 1

Figures 1 and 2

BELLCOMM, INC.

REFERENCES

1. United States Government Memorandum 68-FM74-231, Update of Simplified LM Electrical Power Subsystem Program, Mission Planning and Analysis Division, MSC, Houston, Texas, May 15, 1968.
2. Report No. LED-500-19, Universal Mission Modular Data Book, Grumman Aircraft Engineering Corporation, Bethpage, New York October 15, 1967.
3. Mission Review of the First Lunar Extravehicular Activity, MSC, Houston, Texas, November 1, 1968.
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5. Holloway, T.W., Lunar Landing Mission LM Descent Power Budget, Memorandum CF342-8M-14, Apollo Flight Planning Section, MSC, Houston, Texas, February 16, 1968.
6. Estberg, D. G., Estimation of the Electrical Energy Drawn from the LM Descent Stage Batteries During a Lunar Landing Mission, Working Note to Mr. T. L. Powers, Bellcomm, Inc., May 15, 1968.
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TABLE I, PRELIMINARY MISSION G-1 BLOCKS

PHASE NAME	BLOCK NO	MISSION TIME	PHASE TIME	BLOCK RATE X 7.5
COUNTDOWN	1	L20-5 -1. 0. 0.	1.00000	142.00000
LAUNCH TO SLA	2	L20-5 0. 0. 0.	4.16667	83.20000
SLA TO CSM EPS	3	L20-5 4. 10. 0.	.66667	162.20000
CSM SUPPLIES PWR4	CSM	4. 50. 0.	88.05000	.00000
CREW IVT	3	JL2 92. 53. 0.	1.00000	661.99999
CREW IVT	4	JL2 93. 53. 0.	.50000	795.99999
ORBITAL CKOUT	1	JL4 94. 23. 0.	1.00000	1874.00000
ORBITAL CKOUT	2	JL4 95. 23. 0.	1.16667	1298.00000
ORBITAL CKOUT	3	JL4 96. 33. 0.	.66667	1482.00000
ORBITAL CKOUT	4	JL4 97. 13. 0.	.25000	2039.00000
DCKD COAST UNSTG1	L17-5	97. 28. 0.	.66667	1953.00000
DCKD COAST UNSTG1	L17-5	98. 8. 0.	.41667	2004.00000
SEP FROM CSM	1	JL5 98. 33. 0.	.25000	2006.00000
SEP FROM CSM	2	JL5 98. 48. 0.	.33333	2006.00000
SEP FROM CSM	2	JL5 99. 8. 0.	.11667	2223.99990
UNDKD UNSTG CST	2	L17-5 99. 15. 0.	.41667	2190.00000
UNDKD UNSTG CST	2	L17-5 99. 40. 0.	.08333	2190.00000
DPS BURN	1	L8-5 99. 45. 0.	.10000	2192.00000
DPS BURN	2	L8-5 99. 51. 0.	.00833	2597.00000
DPS BURN	3	L8-5 99. 51. 30.	.19167	2192.00000
UNDKD UNSTG CST	2	L17-5 100. 3. 0.	.50000	2192.00000
PWRD DESCENT	1	L10-5 100. 33. 0.	.20000	2322.00000
PWRD DESCENT	1	L10-5 100. 45. 0.	.20000	2322.00000
PWRD DESCENT	2	L10-5 100. 57. 0.	.18333	2688.00000
POST LANDING	1	L6-5 101. 8. 0.	.50000	2117.99990
POST LANDING	2	L6-5 101. 38. 0.	1.00000	1747.00000
POST LANDING	3	L6-5 102. 38. 0.	.50000	1955.00000
LUNAR STAY	1	L18-5 103. 8. 0.	1.00000	1403.00000
LUNAR STAY	2	L18-5 104. 8. 0.	8.00000	1403.00000
LUNAR STAY	1	L18-5 112. 8. 0.	1.00000	1403.00000
LUNAR STAY	3	L18-5 113. 8. 0.	2.00000	1569.00000
EXPLORATION	1	L11-5 115. 8. 0.	3.00000	1295.00000
LUNAR STAY	1	L18-5 118. 8. 0.	1.50000	1239.00000
LUNAR STAY	1	L18-5 119. 38. 0.	1.00000	1650.00000
PRELAUNCH C/O	2	L7-5 120. 38. 0.	1.86667	1720.00000
PRELAUNCH C/O	3	L7-5 122. 30. 0.	.08333	1720.00000
PRELAUNCH C/O	3	L7-5 122. 35. 0.	.05000	1720.00000
ASCENT FROM SURF1	L13-5	122. 38. 0.	.25000	2212.00000
ASCENT FROM SURF1	L13-5	122. 53. 0.	.25000	2291.00000
ASCENT FROM SURF2	L13-5	123. 8. 0.	.11667	2301.00000
ASCENT FROM SURF3	L13-5	123. 15. 0.	.10000	2291.00000
ASCENT COAST	3	L17-5 123. 21. 0.	.25000	2291.00000
RCS TRANS	1	L5-5 123. 36. 0.	.15000	2295.40000
RCS TRANS	2	L5-5 123. 45. 0.	.01667	2532.90000
ASCENT COAST	3	L17-5 123. 46. 0.	.06667	2290.00000
ASCENT COAST	3	L17-5 123. 50. 0.	.25000	2291.00000
ASCENT COAST	3	L17-5 124. 5. 0.	.05000	2291.00000
ASCENT COAST	3	L17-5 124. 8. 0.	.18333	2291.00000
RCS TRANS	1	L5-5 124. 19. 0.	.15000	2295.40000
RCS TRANS	2	L5-5 124. 28. 0.	.01667	2532.90000
ASCENT COAST	3	L17-5 124. 29. 0.	.06667	2290.00000
ASCENT COAST	3	L17-5 124. 33. 0.	.41667	2214.70000
RCS TRANS	1	L5-5 124. 58. 0.	.16667	2219.10000
RCS TRANS	2	L5-5 125. 8. 0.	.00278	2456.60000
ASCENT COAST	3	L17-5 125. 8. 10.	.06389	2214.70000
ASCENT COAST	3	L17-5 125. 12. 0.	.50000	2291.00000
RCS TRANS	1	L5-5 125. 42. 0.	.16667	2295.40000

TABLE I (CONTINUED)

RCS TRANS	2	L5-5	125. 52. 0.	.00750	2532.90000
ASCENT COAST	3	L17-5	125. 52. 27.	.65917	2290.00000
PREP FOR DOCK	1	JL7-5	126. 32. 0.	.08333	1813.60000
PREP FOR DOCK	2	JL7-5	126. 37. 0.	.08333	1813.00000
PREP FOR DOCK	3	JL7-5	126. 42. 0.	.16667	1245.10000
INV TO CSM	1	JL3-5	126. 52. 0.	.63333	1245.10000
INV TO CSM	2	JL3-5	127. 30. 0.	1.00000	1230.20000
INV TO CSM	3	JL3-5	128. 30. 0.	.13333	911.10000

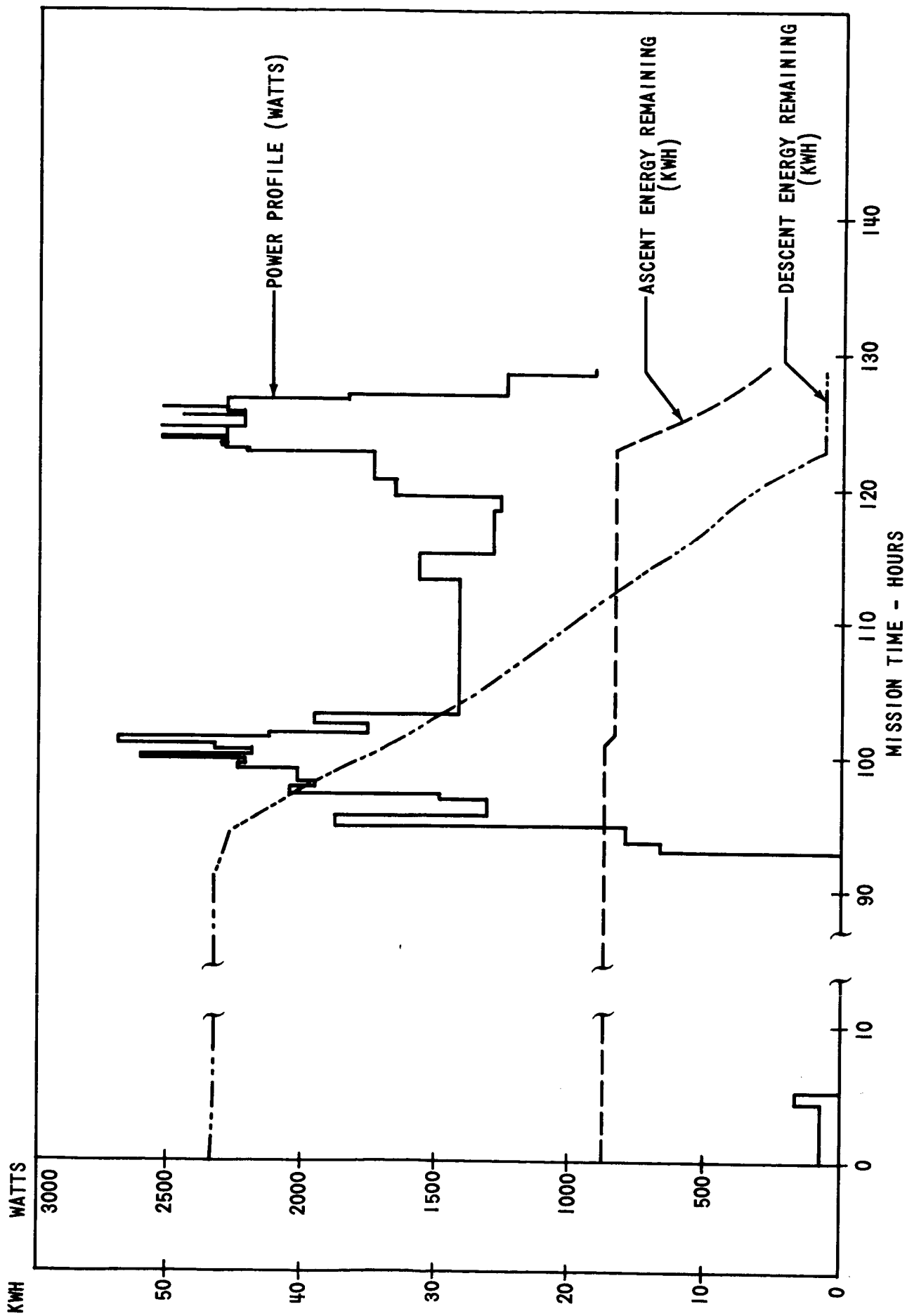


FIGURE 1 - POWER PROFILE AND ENERGY REMAINING

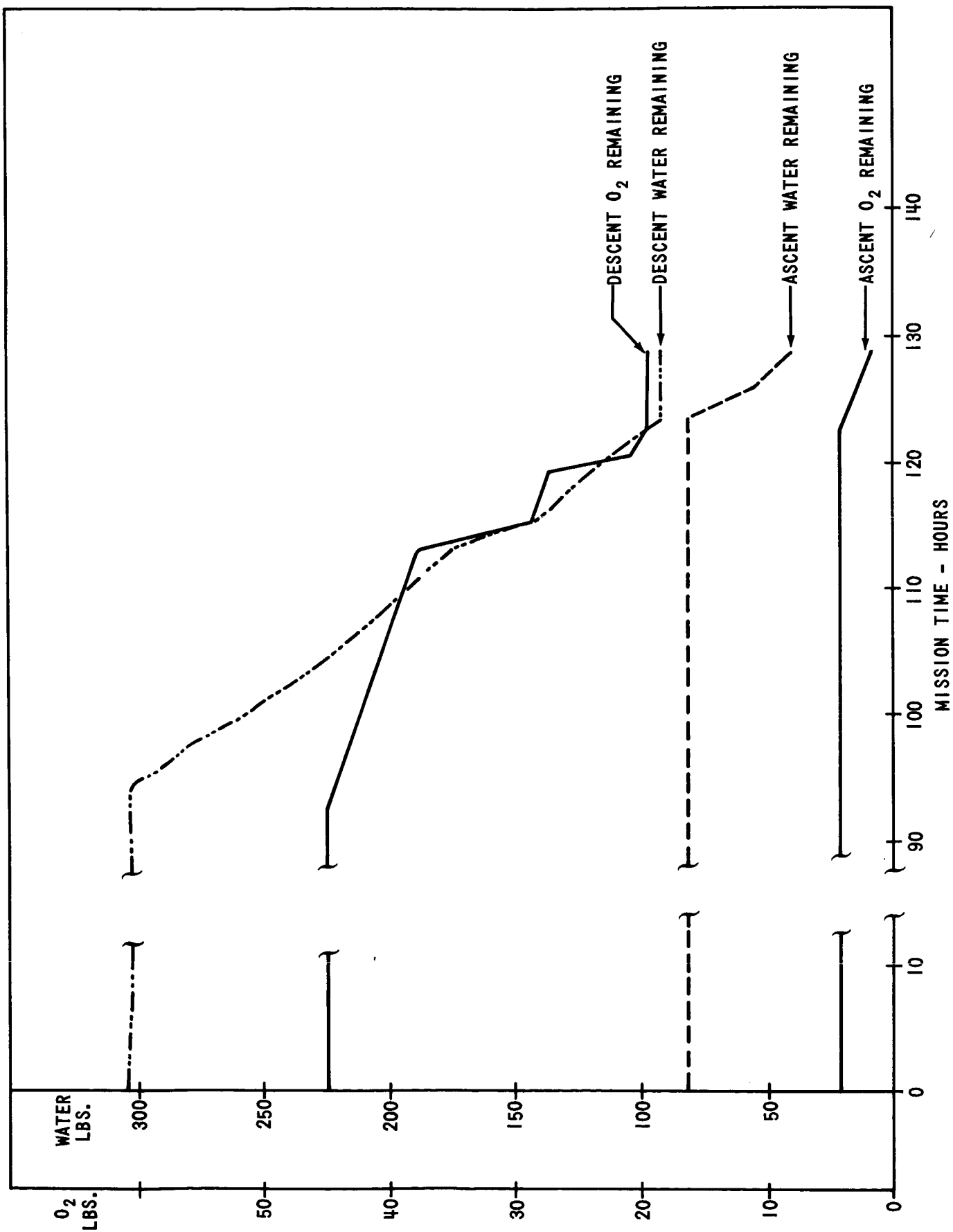


FIGURE 2 - WATER AND OXYGEN REMAINING